Resurvey of Northern Abalone, *Haliotis kamtschatkana*, Populations in Southeast Queen Charlotte Islands, British Columbia, May 2007

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RESURVEY OF NORTHERN ABALONE, *Haliotis kamtschatkana*, POPULATIONS IN SOUTHEAST QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA, MAY 2007

by

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ABSTRACT

Hankewich, S., Lessard, J. and Grebeldinger, E. 2008. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations in southeast Queen Charlotte Islands, British Columbia, May 2007. Can. Manuscr. Rep. Fish. Aquat. Sci. 2839: vii + 39 p.

Northern abalone, *Haliotis kamtschatkana*, have been protected by harvest closures since 1990 due to continued low population levels. Periodic surveys of index sites have been completed since 1978 to monitor the status of abalone populations in British Columbia (BC). In May 2007, a total of 559 abalone were found at 66 of the 82 index sites surveyed along the southeast coast of the Queen Charlotte Islands (QCI). Mean shell length (SL) was 61.5 mm and 6.3% of abalone surveyed were large adult size (≥100 mm SL). The overall density of abalone was 0.43 ± 0.05 (SE) abalone/m^2. Densities of large adult (≥100 mm SL) and of mature (≥70 mm SL) abalone (0.03 abalone/m^2 and 0.15 abalone/m^2, respectively) were significantly lower in 2007 than all other survey years, with the exception of 2002. The density of immature abalone has significantly increased since the last survey in 2002. Despite a slight, but statistically non-significant, increase in 'all sizes' density over the 2002 values, there has been no clear evidence of a recovery of northern abalone populations in southeast Queen Charlotte Islands since the fishery closure in 1990. Poaching continues to be the main concern preventing the recovery of abalone in southeast QCI, BC.

RÉSUMÉ

Hankewich, S., Lessard, J. and Grebeldinger, E. 2008. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations in southeast Queen Charlotte Islands, British Columbia, May 2007. Can. Manuscr. Rep. Fish. Aquat. Sci. 2839: vii + 39 p.

La pêche de l'ormeau nordique, *Haliotis kamtschatkana*, en Colombie-Britannique est complètement fermée depuis 1990 afin de protéger la conservation de l'espèce. Des relevés à des sites indicateurs ont été effectués par Pêches et Océans Canada depuis 1978 pour surveiller l'état des populations d'ormeaux. En mai 2007, 559 ormeaux ont été mesurés à 66 des 82 sites échantillonnés sur la côte sud-est des Îles de la Reine Charlotte. La longueur moyenne était 61.5 mm et 6.3% des ormeaux échantillonnés étaient de grande taille (≥100 mm de longueur). La densité totale estimée était de 0.43 ± 0.05 (ES) ormeau/m^2. Les densités d'ormeaux de grande taille et mature (≥70 mm de longueur), 0.03 ormeau/m^2 et 0.15 ormeau/m^2, respectivement, étaient significativement inférieur à tous les échantillonnages précédents, sauf celui de 2002. La densité des ormeaux immature a significativement augmenté depuis le dernier échantillonnage en 2002. Malgré une petite, mais non significative, augmentation de la densité totale comparativement à la valeur de 2002, il n'y a pas d'indication claire que la population d'ormeaux se rétablie sur la côte sud-est des Îles de la Reine Charlotte depuis la fermeture de la pêche en 1990. Le braconnage continue d'être la cause principale empêchant le rétablissement des ormeaux.

INTRODUCTION

Generally occurring in patchy distributions on exposed or semi-exposed coastlines in British Columbia (BC), the northern abalone, *Haliotis kamtschatkana* Jonas, 1845 (henceforth referred to simply as 'abalone'), is found from Alaska to Baja California (McLean 1966). Until 1990, First Nations harvested northern abalone as a traditional food source, and abalone were a target of recreational divers and a commercial fishery in BC (Campbell 2000). The biology and fishery of the northern abalone were reviewed by Sloan and Breen (1988) and Farlinger and Campbell (1992).

Since 1978, the Department of Fisheries and Oceans Canada (DFO) has assessed northern abalone stocks through surveys of index sites in the southeast Haida Gwaii (Queen Charlotte Islands (QCI)) (Pacific Fishery Management Area (PFMA) 2 east), and the north central coast of BC (CC) (PFMA 5 and 6) using a standard survey design (Breen and Adkins 1979). Much of the commercial fishery for northern abalone was conducted in these areas during 1977-1990 (Harbo 1997). Between 1978 and 1990, northern abalone abundance declined by 75-80% at surveyed sites in CC and QCI (Thomas et al. 1990; Farlinger et al. 1991; Campbell 2000). As a result of this substantial decline and ensuing conservation concerns, DFO banned the harvest of northern abalone in December of 1990. Despite the harvest closure, their numbers remained low and in 1999 northern abalone was listed as '*threatened*' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Campbell 2000; Jamieson 2001). In June 2003, northern abalone was legally listed and protected as threatened under the Species at Risk Act (SARA) (Fisheries and Oceans Canada 2007).

As a consequence of the COSEWIC listing, a National Recovery Strategy for the Northern Abalone was prepared by DFO and the Abalone Recovery Team (Abalone Recovery Team 2002). The initial short-term measurable objective set out in the recovery strategy was: "[to] ensure that mean densities of adult (≥100 mm shell length (SL)) northern abalone do not decline below 0.1/m^2 at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites without adult (≥100 mm SL) northern abalone does not increase to greater than 60%". In September of 2007, the goals of the recovery strategy (Fisheries and Oceans Canada 2007; Lessard et al. 2007), relevant to the QCI (objective #2 excluded) were expanded and revised to:

1) Observe that mean densities of large adult (> 100 mm SL) northern abalone do not decline below 0.1 per m^2 at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites with large adult (>100mm SL) northern abalone does not decrease below 40%.

3) Observe at the index sites (in areas without sea otters) that the annual estimated mortality rate for northern abalone is reduced to <0.20 and the mean densities of mature (≥ 70 mm SL) northern abalone are increased to ≥0.32 per m^2.

4) Observe at the index sites (in areas without sea otters) that the proportion of quadrats (m^2) with northern abalone is increased to > 40%.

In order to monitor northern abalone populations and evaluate recovery efforts, surveys of index sites have continued. This report presents the results of the survey in the southeast QCI (Fig. 1) in May 2007 and compares abalone size frequency and density estimates with those measured in previous surveys.

METHODS

SURVEY METHODS

Nine abalone surveys have been completed in southeast QCI since 1978 (Breen and Adkins 1979; 1981; Boutillier et al. 1985; Carolsfeld et al. 1988; Thomas et al. 1990; Winther et al. 1995; Campbell et al. 2000; Atkins et al. 2004). During the first survey in 1978, 108 sites were surveyed using the standard 'Breen' method described below. Only 10 sites were surveyed in 1979, of which 8 were repeats from the 1978 surveys. In 1984, in addition to 62 sites of the 1978 survey, new sites were selected based on consultations with commercial fishers. In 1987, 1990 and 1994, most of the sites surveyed in 1984 were repeated. In 1998, additional sites were randomly selected and surveyed along with the 'index sites' (sites repeatedly surveyed) to determine if index sites had similar abundances to surrounding areas. Most sample sites surveyed in1984 and later were resurveyed in 2002 and 2007, though random sites from 1998 were excluded. In order to increase sample size in some areas (see below), 9 previously surveyed sites from 1978 and 1979 and 2 random sites surveyed in 1998 were added in 2007. As the surveyed sites in the early years (1978-1983) were selected because they supported strong abalone populations which were deemed harvestable, the sites added in 2007 possessed relatively high abalone density (>1 abalone/m^2; see Appendix 4) in their original surveys in order to keep the initial densities similar across index sites.

Mainly for logistical reasons, the sites were grouped into eight general areas: Cumshewa Inlet, Selwyn Inlet, Tanu Island, Juan Perez Sound separated into Upper Juan Perez and Lower Juan Perez, Skincuttle Inlet, Carpenter Bay, and Kunghit Island (Fig. 1). In 2007, the boundary between Upper and Lower Juan Perez was changed, resulting in 6 sites (sites 36 to 41) previously considered to be in Upper Juan Perez shifting to Lower Juan Perez. While a serial spatial analysis was not carried out in this report, it is hoped that by increasing the sample size within each area, spatial analysis will be possible in the future.

The Coast Guard research vessel *CCGS Vector* acted as a live-aboard platform for the survey crew. Two dive teams, which consisted of three DFO divers and three Haida Fisheries divers, worked from two smaller dive boats, between May 4-16, 2007.

Site positions were located from previous chart records, written site descriptions, photographs and GPS positions. Abalone sites were surveyed using the method described by Breen and Adkins (1979). Once each site was located, divers placed a 1m^2 quadrat at the top of the abalone habitat zone and then sampled 16 quadrats within a 7m by 16m area. The 16 quadrats were arranged in four transects, each 4m apart; and each of the four quadrats within a transect, were 1m apart (i.e. every 2nd quadrat per transect). For each quadrat, divers recorded the algae percent cover and dominant

species, the number of sea urchins and any predators. After recording the habitat data, divers cleared the quadrat of all kelp, sea urchins, and sea stars to ensure all exposed abalone were easily detectable. Divers then recorded the depth and substrate type, and measured, with callipers, the shell length (SL in mm) of each exposed abalone. In previous years, if no abalone were encountered in the first eight quadrats, the dive was aborted and the site count was scored as zero. Following the recommendation of the 2002 survey report (Atkins et al. 2004), all 16 quadrats were sampled at all sites, regardless of whether an abalone was found in the first eight.

In the 1984, 1987 and 1990 surveys, divers turned boulders and rocks in search of hidden or cryptic abalone, but, in an effort to conserve time and increase sample size, only exposed abalone were recorded on the 2007 survey. Searching for cryptic abalone is time-consuming and only 15-17% more abalone are seen during a cryptic search (Cripps and Campbell 1998; Campbell and Cripps 1998). Data for cryptic abalone were excluded from the analyses in this report.

ANALYTICAL METHODS

Due to the boundary modification between upper and lower Juan Perez, and the correction of some errors in the database, some of the size frequency and density estimates in this report may be slightly different from values calculated in previous publications.

A Kolmorgorov-Smirnov two-sample test (SYSTAT 2000) was used to test for differences in mean shell length (SL) between each of the eight general survey areas in 2007. To compare difference in mean SL between survey years, index sites were combined and a one-way ANOVA was used; if differences were detected at the 0.05 confidence level, a post-hoc Bonferroni test was used for comparisons between years.

Abalone densities were expressed as the number/m^2 for several size categories: all sizes, immature (<70 mm SL), mature (≥70 mm SL) and large adult (≥ 100 mm SL). Although some abalone are mature at 50 mm SL, 100% maturity is attained at approximately 70 mm SL (Campbell et al. 1992). The large adult size category was previously referred to as 'legal', i.e. the minimum size in the former commercial fishery that allowed for the abalone to mature and spawn at least once before being harvested. In previous publications, densities were also calculated for 'pre-recruit' and 'new recruit' size categories. These densities referred to abalone abundances just prior to entering the fishery and newly fishery-recruited abalone. However, as the abalone fishery has been closed for more than 16 years and these size categories are now comprised of so few individuals that they have become meaningless, 'pre-recruit' and 'new recruit' densities were not calculated in this report.

Occasionally, the number of abalone measured at a site did not match the number counted, as some abalone were inaccessible or their shells were broken. For this reason, the size frequencies for each site were used to estimate the proportion of abalone within each size category. Densities for each size category (d_i) were calculated as:

$$d_i = \frac{n_i}{n} \times d \qquad (1)$$

where n_i is the number of abalone measured in size category i, n is the total number of abalone measured in the sample and d is the density (abalone/m^2) calculated from the total abalone count from the 16 quadrats. In 1978, abalone were not measured at all sites, but the large adult proportion was estimated. Therefore 1978 density estimates for immature and mature abalone could not be calculated for 57 sites (out of 108). For all survey years, densities of immature abalone should be treated with caution due to the difficulty of detecting small individuals (<70mm SL).

The Kruskal-Wallis test (SYSTAT 2000) was used to compare densities between areas in 2007, as well as between all years (areas combined) for each size category (all sizes, immature, mature and large adult abalone). If differences were detected at the 0.05 confidence level, a Mann-Whitney U was used for comparisons between years. All differences were considered statistically different at the $P< 0.05$ confidence level.

Mortality rate for 'all sizes' abalone was estimated using the 2002 and 2007 survey data and established growth models based on the method described in Zhang et al. (2007). The 2002 size frequency distribution and density estimate (including cryptic proportion calculated from established relationship) were used to predict the density of abalone in 2007. The mortality rate was estimated by comparing the predicted density with the 2007 observed density estimate.

RESULTS

SURVEY SUMMARY

An average of 27.8 minutes (minimum 13, maximum 59) was spent sampling each site (Appendix 1). All sites surveyed had characteristics of abalone habitat (Sloan and Breen 1988; Lessard and Campbell 2007). In general, the sites consisted of bedrock and/or boulders. *Macrocystis integrifolia*, *Nereocystis luetkeana*, *Pterygophora californica* and *Laminaria* spp. were the dominant kelp species (Appendix 2). Encrusting coralline algae were present at all sites. Most sites contained high densities of sea urchins, with a mean of 5.4 ± 0.5/m^2 (SE) and ranging 0-25.8/m^2 (Appendix 1). Although urchin species were not distinguished, the majority were the red sea urchin, *Strongylocentrotus franciscanus*.

SIZE FREQUENCY

In total, 559 abalone were measured during the 2007 survey (Table 1). Mean SL for each site are presented in Appendix 3. The mean SL was 61.5 mm; the smallest abalone measured was 4 mm (Lower Juan Perez) and the largest was 132 mm (Skincuttle Inlet), (Table 1; Fig. 2). Excluding Cumshewa Inlet, where no abalone were found, there was one area (Selwyn Inlet) where no large adult abalone were found.

Lower Juan Perez had the smallest mean SL (46.8 mm SL), which was significantly smaller than all other areas. The largest mean SL (79.0 mm SL) was in the Tanu Island area and was significantly larger than all other areas (Tables 1, 2).

While the range of measurements was large in all years (Fig. 3; Table 3), the overall mean size (61.5 ± 1.0 mm SL) of abalone in the 2007 QCI survey was the smallest observed size of all survey years and was significantly different from all other years, except 2002 (Table 4).

DENSITY

Density estimates by size categories for all sites surveyed in 2007 are presented in Appendix 3. For each 'index site', total density estimates and the number of quadrat sampled across all survey years are presented in Appendix 4; while mature and large density estimates are in Appendix 5.

In the seven general survey areas with abalone, densities for 'all sizes' ranged from 0.289 abalone/m^2 in Selwyn Inlet to 0.781 abalone/m^2 in Lower Juan Perez (Table 5). The 'all sizes' density in Lower Juan Perez was significantly higher than those in Selwyn Inlet, Carpenter Bay and Kunghit Island. Lower Juan Perez also had significantly higher densities of immature abalone (<70mm SL) than all other areas except Upper Juan Perez and Skincuttle Inlet. Tanu Island had significantly more mature abalone (≥ 70mm SL) than Carpenter Bay. Tanu Island also had the highest density of large adult (≥ 100mm SL) abalone, though this difference was not significant when compared to any of the other areas (Table 5).

Abalone densities declined significantly between 1978 and 1984, and have since fluctuated (Fig. 4). 'All size' abalone densities were significantly higher in 1978-1979 than all subsequent survey years (Tables 6, 7). The 2007 'all sizes' density estimate increased from 2002, but this difference was not significant. The density of large adult and mature abalone was significantly lower in 2002 and 2007 than all previous survey years. However, the density of immature abalone in 2007 was significantly higher than the 2002 estimate (Tables 6, 7).

PERCENT OF SITES WITH ABALONE

Abalone were found at 66 (80.5%) of the 82 sites surveyed, and 18.3% of the sites surveyed had exposed large adult abalone in 2007 (Table 8; Fig. 5). Despite an increase in the number of sites sampled, no abalone were found in the Cumshewa Inlet area. All other areas had abalone in each size category, except for Selwyn Inlet, where no large adult abalone were found. The percent of sites within each area with any abalone and large adult abalone ranged from 0% to 100% and 0% to 33.3%, respectively (Table 8).

Across survey years, the percentage of sites with abalone present decreased from 94.4% in 1978 to 80.5% in 2007 (Fig. 5). The latter estimate was a large increase over the 2002 estimate of 69.1% of sites with abalone. However, this increase may be an artefact of the change in protocol to sample all 16 quadrats at each site. In 12 of the sites sampled in 2007, abalone were found only after the first 8 quadrats (Fig. 6). Consequently, if the site survey had not continued beyond the first 8 quadrats, 18.2% of the sites where abalone were found in the current survey would have been scored as zero. The percentage of sites with large adult abalone has continued to decline from 70.4% in 1978 and 25.0% in 2002 to the current estimate of 18.3% (Fig. 5).

PROPORTION OF QUADRATS WITH ABALONE

The proportion of abalone (count/m^2) found in secondary sampling units (quadrats) at index sites declined drastically from 1978 to 1990, and continued to decrease between 1990 and 2007 (Fig. 7). Conversely, the estimated proportion of quadrats with zero abalone increased from the earliest survey in 1978 (when the fishery was active) to the present survey in 2007. Thus, despite the fishery closure in 1990, the likelihood of encountering more than 1 abalone per quadrat has decreased substantially.

MORTALITY RATE

The estimated annual mortality rate of abalone in the QCI is 0.32 ± 0.047 SD (standard deviation).

DISCUSSION

The mean size of QCI abalone in 2007 was significantly smaller than estimates from every other survey year since 1978, with the exception of 2002. The decrease in mean size was due to a combination of an increase in the density of small individuals, a decrease in density of large animals, and a decrease in maximum SL. The overall increase in density between 2002 and 2007 is entirely due to a large increase in the density of immature abalone, as the mature portion showed no change and the density of large abalone declined.

In the absence of harvest and sea otter predation, an accumulation of large abalone is expected for this long-lived species, as was seen prior to the expansion of the commercial fishery in the late 1970's (Breen 1986). Populations with few small and many large individuals are common in other *Haliotis* sp. (Sainsbury 1982; Clavier and Richard 1986; Tegner et al. 1989; Schiel and Breen 1991; Shepherd and Baker 1998), which is largely due to low adult natural mortality (Harrison 1986; Tegner et al. 1989). This natural phenomenon may be compounded by the current survey design, which does not include searching for cryptic juvenile abalone. Similar trends are seen in other long-lived, sporadic-spawning invertebrates, such as red sea urchins (*Strongylocentrotus franciscanus*) (Campbell et al. 2001). However, an accumulation of large adults has not been evident in the Queen Charlotte Islands for several years.

Currently, abalone populations in the QCI are heavily skewed towards higher densities of immature individuals. This trend was also observed in the central coast abalone in 2006 (Hankewich and Lessard 2008). Oceanic conditions appear to have been favourable for abalone reproduction over the last few years; the density of immature abalone in 2007 was the highest it had been since the survey in 1979. Yet, the densities of mature and large abalone were not increasing correspondingly in the past. Obviously, abalone in BC were either experiencing mortality before reaching maturity, or their addition to the mature and large populations was offset by mortality of existing large and mature abalone.

The estimated mortality of abalone from this survey (0.32) falls within the range estimated by Breen (1986) for an exploited abalone population of 0.21-0.41 and is higher than his estimate of natural mortality of 0.15-0.20. This suggests that abalone

harvest is still occurring in the QCI (Lessard et al. 2007). Poaching is considered to be an important threat for abalone populations in BC (Jubinville 2000; Abalone Recovery Team 2002; Lessard et al. 2007), and is a size selective activity which contributes to the decline in large abalone populations (Atkins et al. 2004; Tegner et al. 1989; McShane et al. 1994). While further decline of mature and large abalone is expected to have considerable impacts on recruitment, it appears that mature abalone densities in BC have not yet reached the threshold value where recruitment would fail.

There is still no evidence of abalone populations rebuilding in the southeast QCI in the 16 years since abalone were protected by harvest closures. Although 'all sizes' density increased since the last survey, the difference was not statistically significant, and the large adult abalone density continued to decline.

The four goals set in the National Recovery Strategy for the Northern Abalone (Fisheries and Oceans Canada 2007) have not yet been met in Haida Gwaii: the mean density of large adult and mature abalone are only at 0.03 abalone/m^2 and 0.15 abalone/m^2, respectively, well below the short-term objectives of maintaining densities at or above 0.1 abalone/m^2 and 0.32 abalone/m^2. The percentage of sites with large adult abalone fell below the goal of 40% in 2002 (25.0%), and continued to decline in the 2007 survey (18.3%). Furthermore, the proportion of quadrats with abalone was below 25%, far from the abalone recovery strategy's goal of 40%. The annual estimated mortality rate for abalone in the QCI was 0.32, which is above the goal of less than 0.20.

The decline in densities of mature and large abalone, while immature abalone density increased, suggests that the main factor preventing recovery was probably not low recruitment, but poaching. In order for abalone in BC to recover, this mortality must be addressed; the immature abalone present today must be allowed to reach maturity, and the decline of large adult abalone must be halted to ensure continued recruitment.

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REFERENCES

Abalone Recovery Team. 2002. National Recovery Strategy for the Northern Abalone (*Haliotis kamtschatkana*) in Canada. 22 pp. http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/abalone/documents/04Abalone_RS.pdf (Accessed Jan 2008)

Atkins, M., Lessard, J., and Campbell, A. 2004. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations in Southeast Queen Charlotte Islands, British Columbia, April 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2704: 37 p.

Boutillier, J.A., Carolsfeld, W., Breen, P.A., Farlinger, S., and Bates, K. 1985. Abalone resurvey in the southeast Queen Charlotte Islands, July 1984. Can. Manuscr. Rep. Fish. Aquat. Sci. 1818: 87 p.

Breen, P.A. 1986. Management of the British Columbia fishery for northern abalone (*Haliotis kamtschatkana*). Can. Spec. Publ. Fish. Aquat. Sci. 92: 300-312.

Breen, P.A., and Adkins, B.E. 1979. A survey of abalone populations on the east coast of the Queen Charlotte Islands, August 1978. Fish. Mar. Serv. Manuscr. Rep. 1490: 125 p.

Breen, P.A., and Adkins, B.E. 1981. Abalone surveys and tagging conducted during 1979. Can. Manuscr. Rep. Fish. Aquat. Sci. 1623: 88 p.

Campbell, A. 2000. Review of northern abalone, *Haliotis kamtschatkana*, stock status in British Columbia. Can. Spec. Publ. Fish. Aquat. Sci. 130. pp. 41-50.

Campbell, A., Brouwer, D., Rogers, J., and Miller, D.C. 2000. Abalone resurvey in south east Queen Charlotte Islands, 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2528: 30 p.

Campbell, A., Tzotzos, D., Hajas, W.C., and Barton, L.L. 2001. Quota options for the red sea urchin fishery in British Columbia fishing season 2002/2003. Can. Sci. Advis. Secret. Res. Doc. 2001/141: 47 p.

Campbell, A., and Cripps, K. 1998. Survey of abalone populations at Stryker Island, Tribal Group and Simonds Group, Central Coast of British Columbia, May 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2451: 21 p.

Campbell, A., Manley, I., and Carolsfeld, W. 1992. Size at maturity and fecundity of the abalone, *Haliotis kamtschatkana*, in northern British Columbia. Can Manuscr. Rep. Fish. Aquat. Sci. 2169: 47-65.

Carolsfeld, W., Farlinger, S., Kingzett, B.C., Sloan, N.A., and Thomas, G. 1988. Abalone resurvey in the southeast Queen Charlotte Islands, June 1987. Can. Manuscr. Rep. Fish. Aquat. Sci. 1966: 90 p.

Clavier, J., and Richard, O. 1986. Estimation du stock naturel d'ormeaux (*Haliotis tuberculata*) dans la région de Saint-Malo. Rev. Trav. Inst. Pêches Marit. 48: 95-105.

Cripps, K., and Campbell, A. 1998. Survey of abalone populations at Dallain Point and Higgins Pass, central coast of British Columbia, 1995-96. Can Manuscr. Rep. Fish. Aquat. Sci. 2445: 31 p.

Farlinger, S., and Campbell, A. 1992. Fisheries management and biology of northern abalone, *Haliotis kamtschatkana*, in the northeast Pacific. pp. 395-406 *In* Shepherd, S.A., Tegner, M.J., Guzmán del Próo, S.A. (eds), Abalone of the World - Biology, Fisheries and Culture. Fishing News Books, Oxford.

Farlinger, S., Thomas, G.A., Winther, I., and Carolsfeld, W. 1991. Abalone resurvey in the Estevan Group and Aristazabal Island, June 1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2104: 39 p.

Fisheries and Oceans Canada. 2007. Recovery Strategy for the Northern Abalone (*Haliotis kamtschatkana*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver. *vi* + 31 pp. http://www.sararegistry.gc.ca/plans/showDocument_e.cfm?id=1342 (Accessed Jan 2008)

Hankewich, S., and Lessard, J. 2008. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations along the central coast of British Columbia, May 2006. Can. Manuscr. Rep. Fish. Aquat. Sci. 2838: 41 p.

Harbo, R. 1997. Abalone dive fishery (closed). Can. Manuscr. Rep. Fish. Aquat. Sci. 2369: 86-92.

Harrison, A.J. 1986. Gastropod fisheries of the Pacific with particular reference to Australian abalone, p. 14-22. Can. Spec. Publ. Fish. Aquat. Sci. 92: 14-22.

Jamieson, G.S. 2001. Review of status of northern abalone, *Haliotis kamstchatkana*, in Canada. Canadian Field-Naturalist 115: 555-563.

Jubinville, B. 2000. Enforcing the fishery closure for northern (pinto) abalone (*Haliotis kamtschatkana*) in British Columbia [Abstract]. Can. Spec. Publ. Fish. Aquat. Sci. 130. pp. 52.

Lessard, J., and Campbell, A. 2007. Describing northern abalone, *Haliotis kamtschatkana*, habitat: focusing rebuilding efforts in British Columbia, Canada. J. Shellfish Res. 26: 677-686.

Lessard, J., Campbell, A., Zhang, Z., MacDougall, L., and Hankewich, S. 2007. Recovery Potential Assessment for the northern abalone, *Haliotis kamtschatkana*, in Canada. Can. Sci. Advis. Secret. Res. Doc. 2007/061: 107p.

McLean, J. 1966. West American prosobranch gastropoda: Superfamilies Patellacae, Pleurotomariacea, and Fissurellacea. Ph.D. Thesis, Stanford University. 255 p.

McShane, P.E., Mercer, S.F., and Naylor, J.R. 1994. Spatial variation and commercial fishing of New Zealand abalone (*Haliotis iris* and *H. australis*). New Zealand J. Mar. Freshwat. Res. 28: 345-355.

Sainsbury, K.J. 1982. Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction, and mortality. N.Z. J. Mar. Freshwat. Res. 16: 147-161.

Schiel, D.R., and Breen, P.A. 1991. Population structure, ageing, and fishing mortality of New Zealand abalone *Haliotis iris*. Fish. Bull. 89: 681-691.

Shepherd, S.A., and Baker, J.L. 1998. Biological reference points in an abalone (*Haliotis laevigata*) fishery. Can. Spec. Publ. Fish. Aquat. Sci. 125: 235-245.

Sloan, N.A., and Breen, P.A. 1988. Northern abalone, *Haliotis kamtschatkana*, in British Columbia: fisheries and synopsis of life history information. Can. Spec. Public. Fish. Aquat. Sci. 103: 46 p.

SYSTAT. 2000. SPSS Inc., Chicago, IL, USA.

Tegner, M.J., Breen, P.A., and Lennert, C.E. 1989. Population biology of red abalones, *Haliotis rufescens*, in sourthern California and management of the red and pink, H. corrugate, abalone fisheries. Fish. Bull. 87: 313-339.

Thomas, G., Farlinger, S., and Carolsfeld, W. 1990. Abalone resurvey in the southeast Queen Charlotte Islands in 1990. Can. MS Rep. Fish. Aquat. Sci. 2099: 66-82.

Winther, I., Campbell, A., Thomas, G.A., Adkins, B.E., and Clapp, B.G. 1995. Abalone resurvey in the southeast Queen Charlotte Islands in 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2273: 43 p.

Zhang, Z., Campbell, A., and Lessard, J. 2007. Modelling northern abalone, Haliotis kamtschatkana, population stock and recruitment in British Columbia. J. Shellfish Res. 26: 1099-1107.

Table 1. Summary of exposed abalone shell length data from surveyed sites in each general survey areas on southeast QCI in May 2007. SE = standard error of the mean.

	Shell Length (mm)					Total	Percent large
Area	**Mean**	**Median**	**SE**	**Minimum**	**Maximum**	**Count**	**(≥100 mm SL)**
Cumshewa Inlet	n/a	n/a	n/a	n/a	n/a	0	0
Selwyn Inlet	56.8	56	2.8	18	86	37	0
Tanu Island	79.0	81	2.1	25	118	73	11
Upper Juan Perez	62.5	59	1.8	15	118	122	5.7
Lower Juan Perez	46.8	45	2.2	4	122	125	4.8
Skincuttle Inlet	66.7	64	2.1	18	132	103	8.7
Carpenter Bay	56.3	55	2.3	17	114	55	1.8
Kunghit Island	70.0	71	3.2	30	115	44	9.1
Total	61.5	60	1.0	4	132	559	6.3

Table 2. Probability values of Kolmogorov-Smirnov test comparing mean SL of abalone measured within the general survey areas on the southeast QCI in 2007. Values in bold indicate significant difference ($P<0.05$). Cumshewa Inlet was excluded due to the absence of abalone at index sites.

	Selwyn Inlet	Tanu Island	Upper Juan Perez	Lower Juan Perez	Skincuttle Inlet	Carpenter Bay
Tanu Island	**0.000**					
Upper Juan Perez	0.355	**0.000**				
Lower Juan Perez	**0.006**	**0.000**	**0.000**			
Skincuttle Inlet	0.227	**0.000**	0.264	**0.000**		
Carpenter Bay	0.715	**0.000**	0.158	**0.002**	**0.007**	
Kunghit Island	**0.012**	**0.009**	**0.021**	**0.000**	0.145	**0.000**

Table 3. Summary of exposed abalone shell length data from surveyed sites on the southeast QCI, by year.

	Shell Length (mm)					Total	Percent Large
Year	Mean	Median	SE	Minimum	Maximum	Count	(>100mm SL)
1978	69.5	70	0.6	5	141	2102	11.6
1979	81.8	85	1.2	22	127	360	25.6
1984	74.1	76	1.1	17	140	583	17.8
1987	81.3	82	1.1	10	146	718	30.4
1990	76.8	76	1.1	10	152	581	20.3
1994	77.7	79	1.0	7	150	725	23.3
1998	76.5	76	0.8	11	154	1023	19.0
2002	67.0	68	1.4	8	135	362	12.7
2007	61.5	60	1.0	4	132	559	6.3

Table 4. ANOVA results comparing the mean size of abalone, from all sites, between years. Numbers represent P-values from the multiple comparison Bonferroni test. Values in bold indicate significant difference (P<0.05).

	Year							
Year	1978	1979	1984	1987	1990	1994	1998	2002
1979	**0.000**							
1984	**0.005**	**0.000**						
1987	**0.000**	1.000	**0.000**					
1990	**0.000**	0.150	1.000	0.065				
1994	**0.000**	0.533	0.483	0.297	1.000			
1998	**0.000**	**0.033**	1.000	**0.005**	1.000	1.000		
2002	1.000	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**	**0.000**	
2007	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.064

Table 5. Mean exposed abalone density estimates (number/m^2) by size category and general survey area from all sites surveyed in southeast QCI in 2007. Means followed by the same letter were significantly different ($P<0.05$) from each other using a non-parametric Kruskal-Wallis test (Cumshewa Inlet area was excluded from this analysis). Values in brackets are the standard errors of the mean.

	Cumshewa Inlet	Selwyn Inlet	Tanu Island	U Juan Perez	L Juan Perez	Skincuttle Inlet	Carpenter Bay	Kunghit Island	All sites
Number of sites sampled	9	8	8	14	10	13	11	9	82
All sizes	0.000 (0.00)	0.29 [a] (0.16)	0.57 (0.20)	0.55 (0.17)	0.78 [a,b,c] (0.19)	0.49 (0.08)	0.31 [b] (0.12)	0.31 [c] (0.11)	0.43 (0.05)
Immature (<70 mm SL)	0.000 (0.00)	0.22 [d] (0.06)	0.12 [e] (0.05)	0.36 (0.12)	0.68 [d,e,f,g] (0.18)	0.31 (0.07)	0.26 [f] (0.11)	0.13 [g] (0.05)	0.27 (0.04)
Mature (≥70 mm SL)	0.000 (0.00)	0.07 (0.02)	0.45 [h] (0.17)	0.18 (0.09)	0.11 (0.04)	0.19 (0.06)	0.06 [h] (0.03)	0.17 (0.09)	0.15 (0.03)
Large adult (≥100 mm SL)	0.000 (0.00)	0.00 (0.00)	0.06 (0.05)	0.03 (0.02)	0.04 (0.04)	0.04 (0.02)	0.01 (0.01)	0.03 (0.02)	0.03 (0.01)

Table 6. Mean exposed abalone density estimates (number/m^2) by size category and year from all sites surveyed in southeast QCI. The values in brackets are the standard errors of the mean. * only 51 sites used for density estimates of immature and mature size categories.

	Year								
	1978	1979	1984	1987	1990	1994	1998	2002	2007
Number of sites sampled	108*	10	70	70	69	70	115	68	82
All sizes	2.22 (0.24)	2.34 (0.52)	0.53 (0.06)	0.65 (0.08)	0.46 (0.06)	0.29 (0.04)	0.56 (0.05)	0.34 (0.06)	0.43 (0.05)
Immature (<70 mm SL)	1.39 (0.27)	0.64 (0.22)	0.22 (0.05)	0.24 (0.06)	0.20 (0.03)	0.12 (0.02)	0.22 (0.03)	0.18 (0.04)	0.27 (0.04)
Mature (≥70mm SL)	1.28 (0.24)	1.70 (0.39)	0.30 (0.05)	0.40 (0.05)	0.27 (0.04)	0.17 (0.17)	0.34 (0.04)	0.15 (0.03)	0.15 (0.03)
Large (≥100 mm SL)	0.36 (0.05)	0.55 (0.18)	0.09 (0.02)	0.19 (0.03)	0.10 (0.02)	0.06 (0.01)	0.11 (0.02)	0.04 (0.01)	0.03 (0.01)

Table 7. Mann-Whitney U test probabilities comparing mean abalone densities from all sites in southeast QCI between years, by size category. P-values in bold indicate significant difference (P<0.05).

	Year							
	1978	1979	1984	1987	1990	1994	1998	2002
All sizes								
1979	0.364							
1984	**0.000**	**0.000**						
1987	**0.000**	**0.000**	0.140					
1990	**0.000**	**0.000**	0.631	**0.017**				
1994	**0.000**	**0.000**	**0.046**	**0.000**	0.092			
1998	**0.000**	**0.000**	0.348	0.307	0.057	**0.000**		
2002	**0.000**	**0.000**	**0.009**	**0.000**	**0.023**	0.384	**0.000**	
2007	**0.000**	**0.000**	0.254	**0.004**	0.578	0.269	**0.017**	0.071
Immature (<70mm SL)								
1979	0.547							
1984	**0.000**	**0.008**						
1987	**0.000**	**0.008**	0.647					
1990	**0.000**	**0.007**	0.816	0.773				
1994	**0.000**	**0.001**	0.379	0.122	0.235			
1998	**0.000**	**0.010**	0.156	0.380	0.251	**0.008**		
2002	**0.000**	**0.002**	0.583	0.302	0.458	0.796	**0.049**	
2007	**0.000**	**0.026**	0.117	0.255	0.167	**0.008**	0.650	**0.034**
Mature (≥70mm SL)								
1979	0.162							
1984	**0.000**	**0.000**						
1987	**0.000**	**0.001**	0.054					
1990	**0.000**	**0.000**	0.923	**0.023**				
1994	**0.000**	**0.000**	0.787	**0.002**	0.578			
1998	**0.000**	**0.000**	0.161	0.391	0.127	**0.019**		
2002	**0.000**	**0.000**	**0.041**	**0.000**	**0.022**	**0.034**	**0.000**	
2007	**0.000**	**0.000**	**0.038**	**0.000**	**0.011**	**0.012**	**0.000**	0.924
Large (≥100mm SL)								
1979	0.128							
1984	**0.000**	**0.000**						
1987	**0.020**	**0.007**	**0.031**					
1990	**0.000**	**0.000**	0.739	0.062				
1994	**0.000**	**0.000**	0.784	**0.010**	0.499			
1998	**0.000**	**0.000**	0.865	**0.012**	0.601	0.975		
2002	**0.000**	**0.000**	**0.010**	**0.000**	**0.004**	**0.010**	**0.012**	
2007	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.263

Table 8. Percent of index sites by general survey area with exposed abalone and large adult (≥100 mm SL) abalone, southeast QCI May 2007.

Area	Percent of sites with abalone		Number of sites surveyed
	Total	Large	
Cumshewa Inlet	0.0	0.0	9
Selwyn Inlet	100.0	0.0	8
Tanu Island	75.0	25.0	8
Upper Juan Perez	92.9	28.6	14
Lower Juan Perez	100.0	10.0	10
Skincuttle Inlet	92.3	30.8	13
Carpenter Bay	90.9	9.1	11
Kunghit Island	77.8	33.3	9
All Areas	80.5	18.3	82

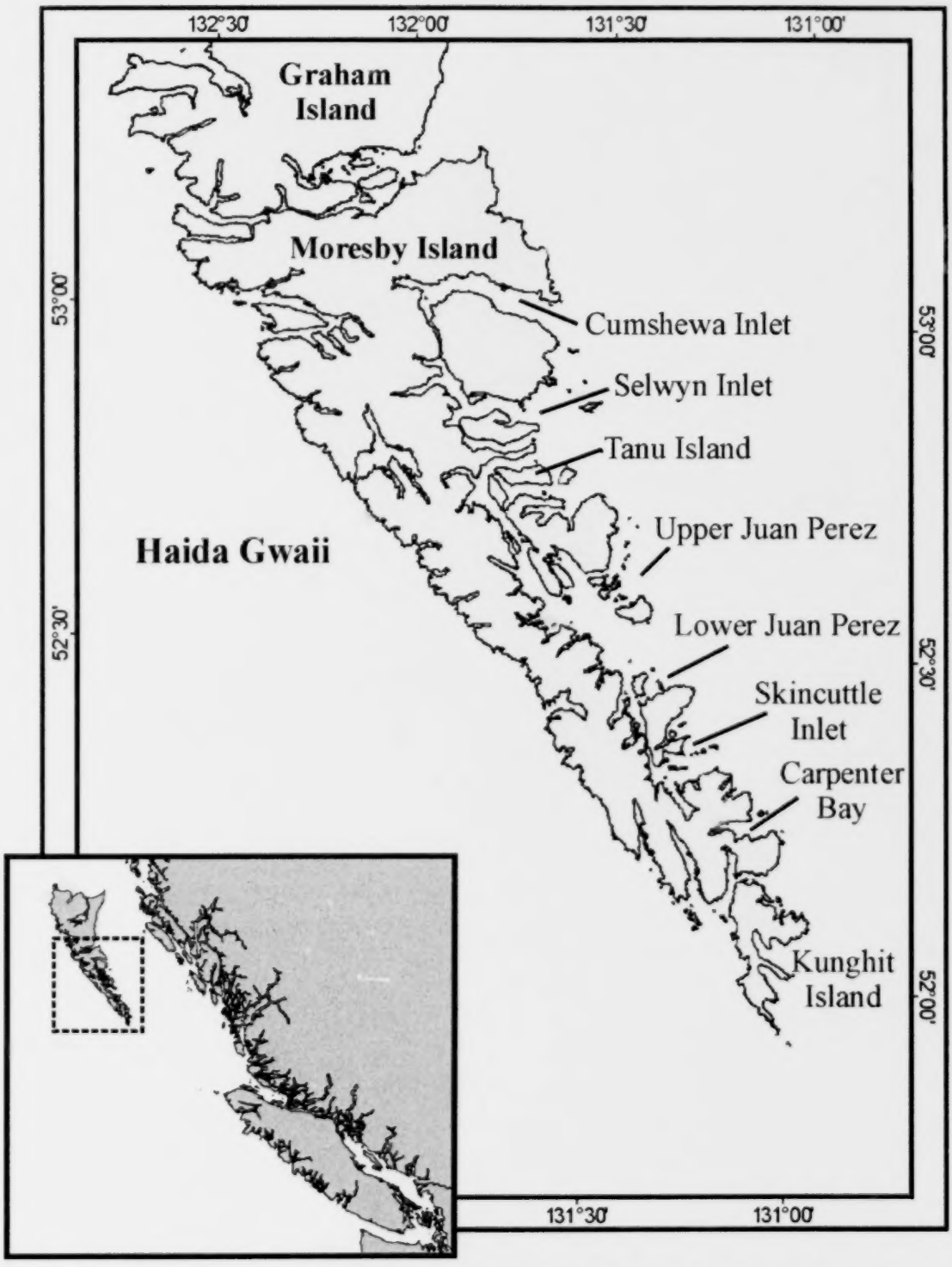

Figure 1. Map of the eight general survey area along the coast of Queen Charlotte Islands, BC.

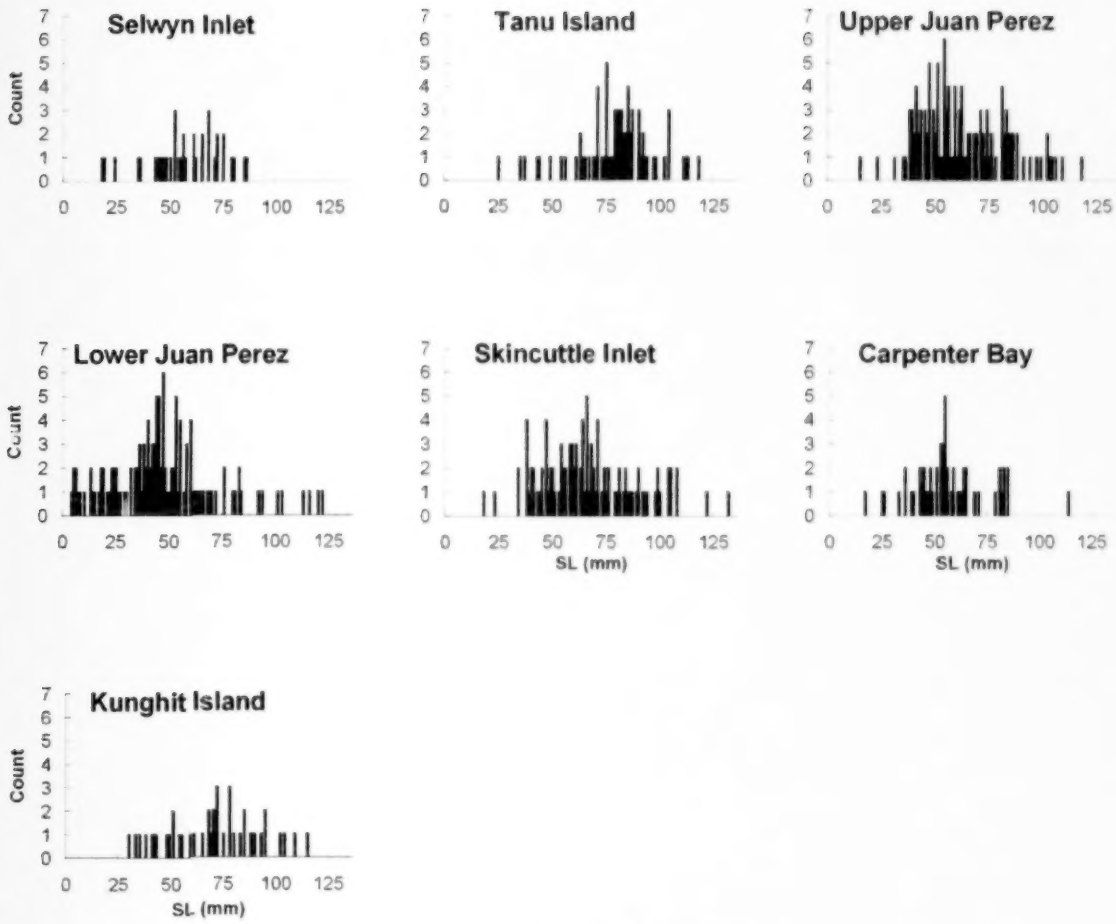

Figure 2. Size frequency of exposed abalone shell lengths measured from all sites in each general survey area on southeast QCI, May 2007. Cumshewa Inlet is excluded as no abalone were measured in this area.

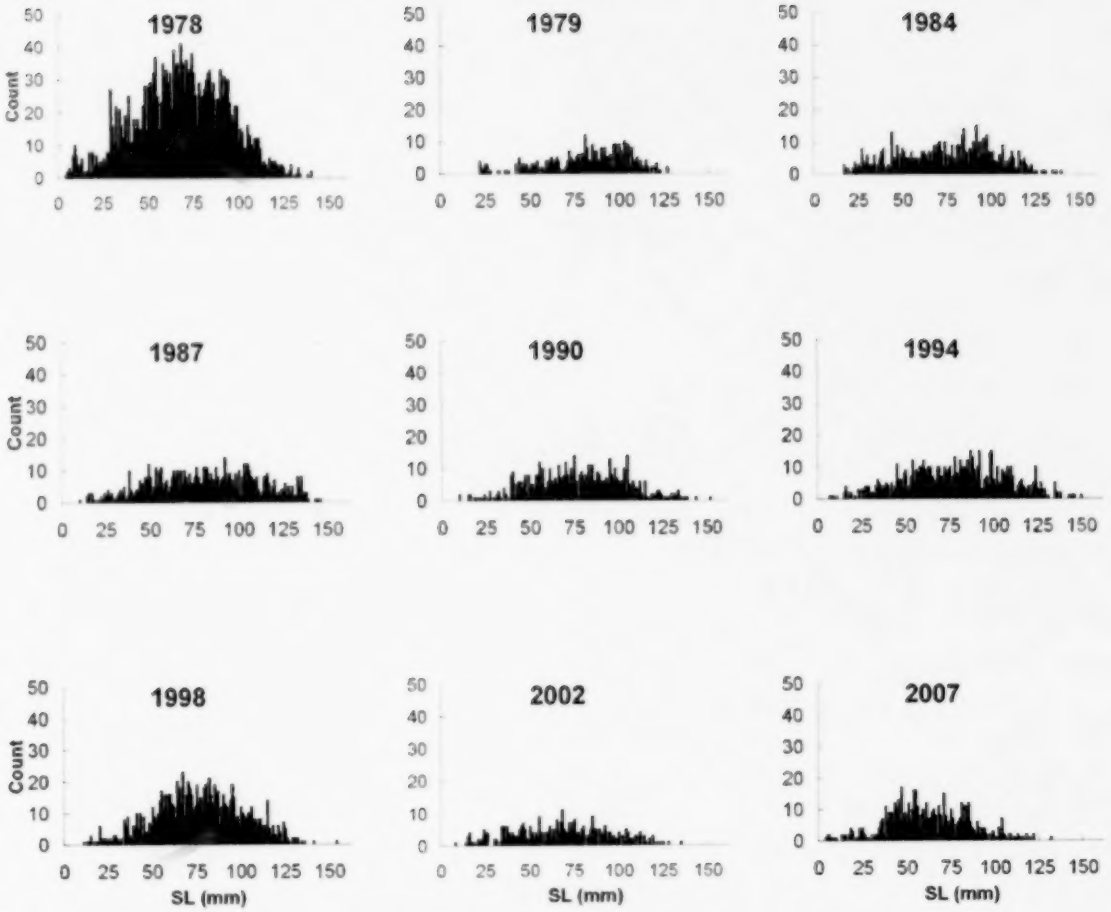

Figure 3. Size frequency of exposed abalone shell lengths measured from all sites for all survey years.

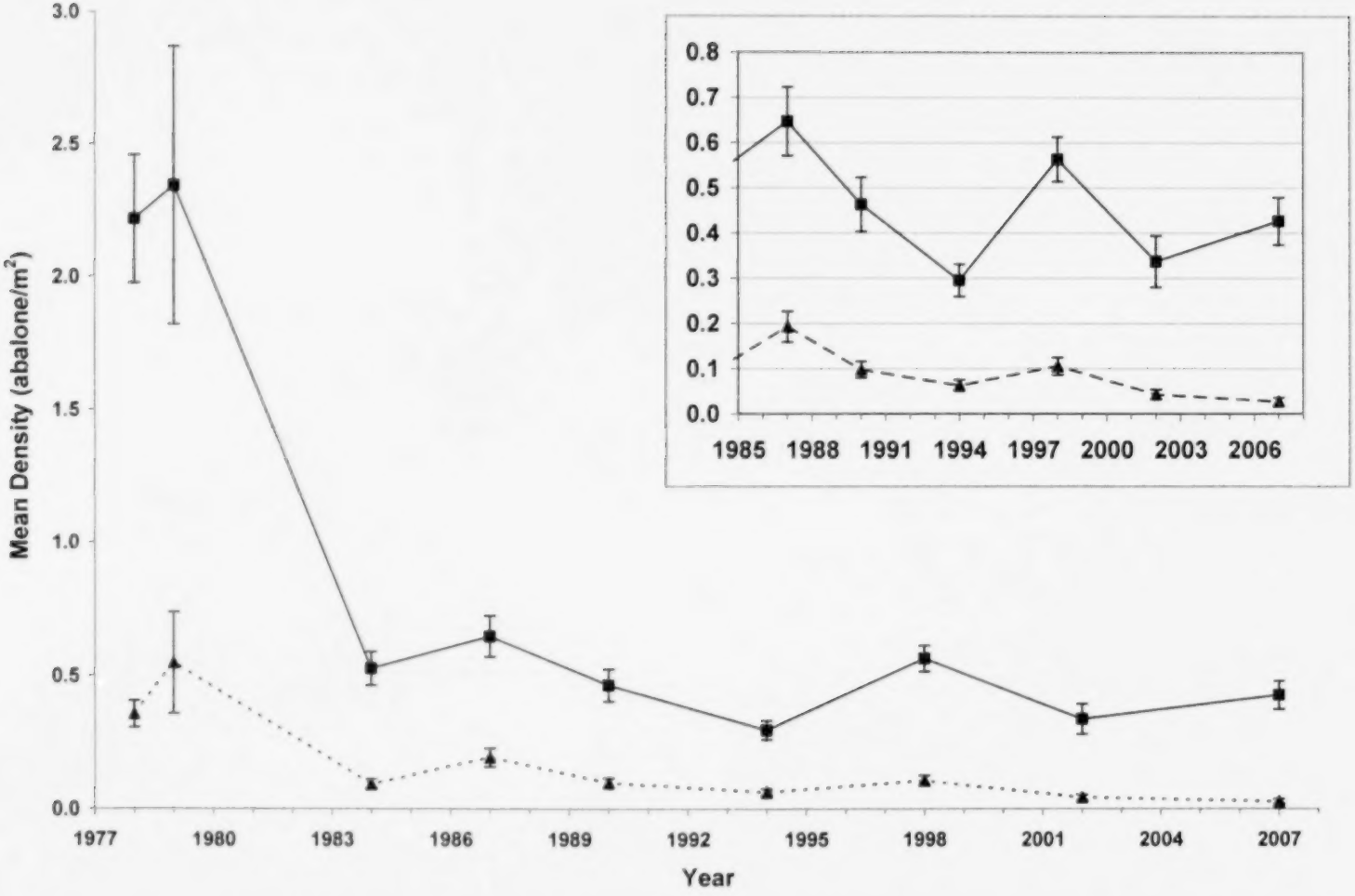

Figure 4. Mean density of 'all sizes' abalone (solid line) and large adult abalone (≥100 mm SL) (dashed line) from all surveys (1978-2007). All sites surveyed are included. Error bars represent SE. Inset graph displays greater resolution of densities for survey years after 1985.

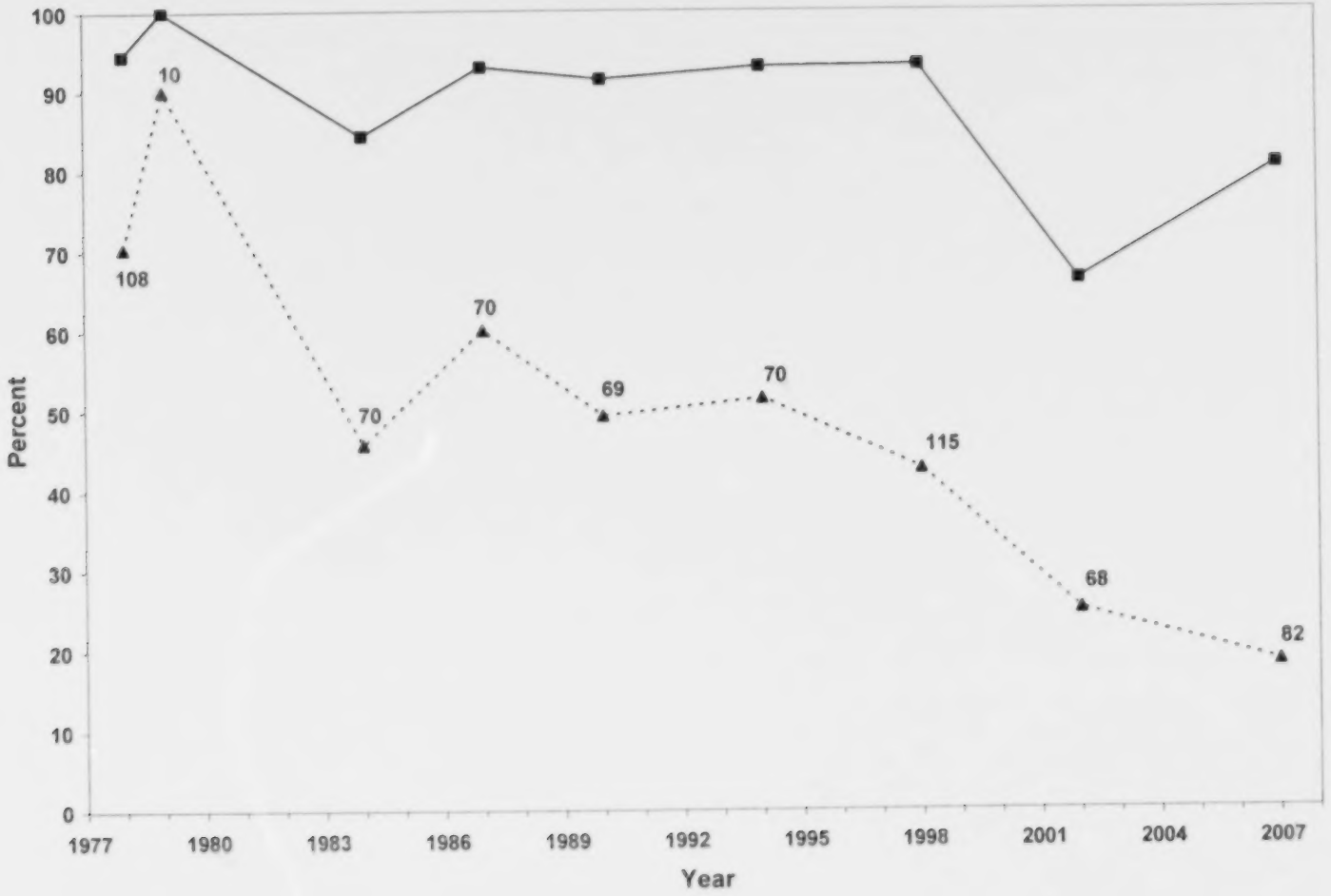

Figure 5. Percent of sites with exposed abalone of 'any size' (solid line) or exposed large adult abalone (≥100 mm SL) (dashed line) from surveys in southeast QCI, 1978-2007. Numbers are sample sizes for each survey year.

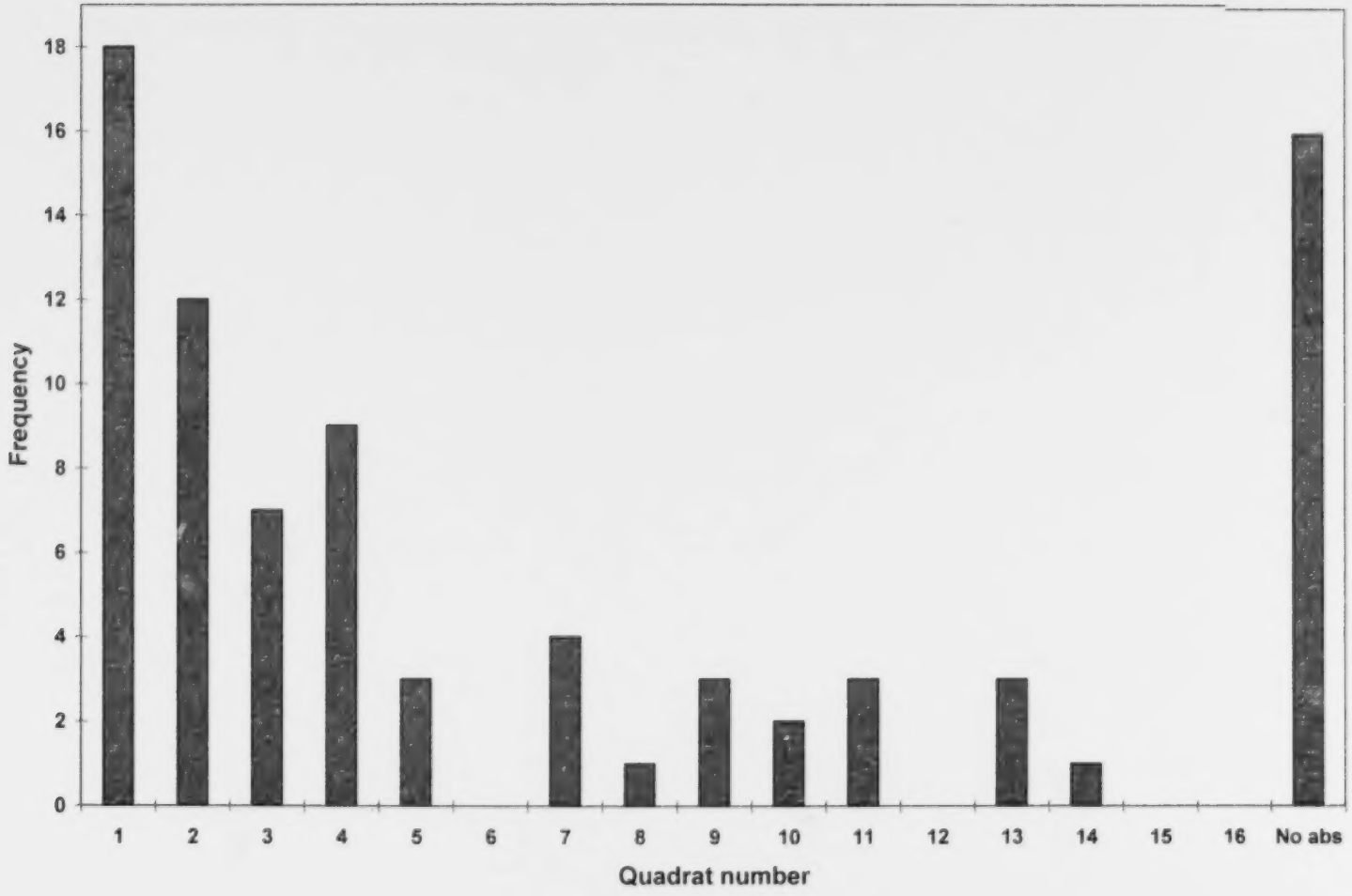

Figure 6. Frequency of the first abalone found at a site for each quadrat number at a given site, for all sites sampled during the 2007 QCI index sites survey. No abs refers to the number of sites where no abalone were measured.

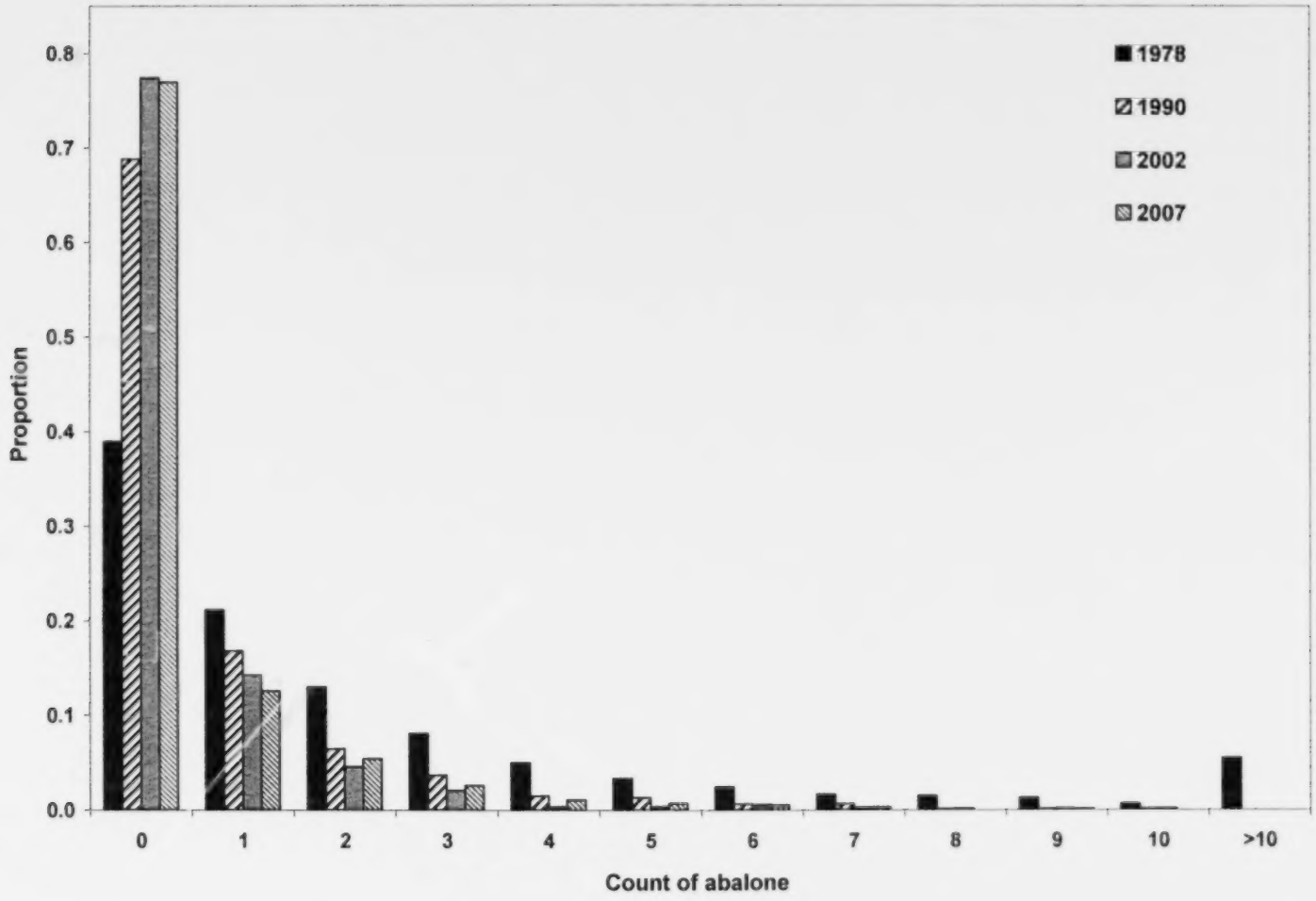

Figure 7. Proportion of quadrats surveyed with different abalone counts (all sizes) from all samples in 1978, 1990 (last survey year when fisheries were opened), 2002 and 2007 surveys on southeast QCI.

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Appendix 1. Dive summary for the southeast QCI survey, May 2007. Density: number/m^2.

Site	Date		Dive Time			Depth (m)		Number of quadrats	Abalone		Urchins	
			Start	Finish	Minutes	Min	Max		Count	Density	Count	Density
Cumshewa Inlet												
75	May	4	9:02	9:40	38	1	2	16	0	0	0	0
76	May	4	9:40	10:00	20	0	3	16	0	0	4	0.25
77	May	4	8:58	9:11	13	3	3	16	0	0	0	0
78	May	4	14:45	15:00	15	3	6	16	0	0	47	2.94
78-10	May	4	13:30	14:10	40	5	8	16	0	0	0	0
78-16	May	4	10:17	10:40	23	4	5	16	0	0	0	0
78-18	May	4	15:20	16:15	55	0	5	16	0	0	77	4.81
79-54	May	4	10:14	10:51	37	2	3	16	0	0	0	0
79-57	May	4	10:55	11:15	20	2	4	16	0	0	128	8
Selwyn Inlet												
65	May	11	9:12	9:35	23	1	2	16	2	0.13	114	7.13
66	May	10	10:36	11:30	54	-2	0	16	6	0.38	196	12.25
67	May	10	8:27	9:21	54	-1	3	16	6	0.38	116	7.25
68	May	10	15:09	15:33	24	2	5	16	2	0.13	53	3.31
69	May	10	15:22	16:14	52	0	7	16	4	0.25	65	4.06
70	May	11	9:37	10:26	49	1	4	16	7	0.44	100	6.25
78-23	May	11	8:24	9:13	49	1	3	16	2	0.13	47	2.94
79-58	May	10	9:37	10:21	44	-1	3	16	8	0.50	177	11.06
Tanu Island												
59	May	9	9:59	10:17	18	-1	2	16	13	0.81	90	5.63
60	May	9	9:30	9:51	21	-2	0	16	21	1.31	79	4.94
61	May	9	13:10	13:50	40	-1	3	16	2	0.13	146	9.13
62	May	9	10:43	11:20	37	-1	1	16	7	0.44	74	4.63
63	May	9	9:45	10:24	39	-1	0	16	23	1.44	142	8.88
64	May	9	10:45	11:05	20	-2	0	16	0	0	0	0
73	May	9	8:36	9:13	37	-1	1	16	7	0.44	4	0.25
74	May	9	8:26	8:51	25	-2	0	16	0	0	0	0
Upper Juan Perez												
44	May	16	9:07	9:41	34	0	3	16	4	0.25	43	2.69
45	May	16	8:23	8:50	27	0	1	16	4	0.25	33	2.06
46	May	15	9:10	9:50	40	0	5	16	29	1.81	286	17.88
48	May	15	8:10	8:50	40	1	3	16	7	0.44	49	3.06
49	May	14	15:38	16:07	29	-1	2	16	8	0.50	90	5.63
50	May	12	14:20	14:43	23	0	1	16	2	0.13	65	4.06
51	May	12	14:55	15:20	25	-1	4	16	0	0	15	0.94
52	May	13	8:32	9:19	47	1	4	16	8	0.50	129	8.06
53	May	12	8:07	8:33	26	0	3	16	9	0.56	232	14.5
54	May	12	13:27	14:04	37	0	2	16	39	2.44	127	7.94
55	May	12	9:47	10:28	41	0	3	16	14	0.88	52	3.25
56	May	12	8:30	9:29	59	-1	1	16	2	0.13	187	11.69
57	May	12	8:47	9:11	24	-2	1	16	1	0.06	412	25.75
58	May	12	10:54	11:24	30	2	5	16	1	0.06	110	6.88

Appendix 1. Continued.

Site	Date		Dive Time			Depth (m)		Number of quadrats	Abalone		Urchins	
			Start	Finish	Minutes	Min	Max		Count	Density	Count	Density
Lower Juan Perez												
36	May	16	9:00	9:23	23	2	7	16	6	0.38	55	3.44
37	May	16	8:30	8:50	20	0	4	16	12	0.75	65	4.06
38	May	16	15:31	16:19	48	0	2	16	30	1.88	85	5.31
39	May	16	14:32	15:07	35	-1	4	16	6	0.38	74	4.63
40	May	16	13:15	14:05	50	-1	2	16	14	0.88	43	2.69
41	May	16	10:00	10:35	35	0	4	16	8	0.50	0	0
42	May	16	10:24	10:53	29	0	5	16	7	0.44	79	4.94
43	May	16	9:34	10:02	28	-1	2	16	10	0.63	85	5.31
78-60	May	16	15:03	15:29	26	-1	4	16	8	0.50	111	6.94
78-61	May	16	13:25	14:03	38	0	5	16	34	2.13	126	7.88
Skincuttle Inlet												
22	May	7	8:45	9:06	21	2	7	16	10	0.63	168	10.5
23	May	7	9:30	9:51	21	-1	0	16	6	0.38	45	2.81
24	May	8	12:59	13:27	28	0	2	16	13	0.81	2	0.13
25	May	8	13:52	14:21	29	-1	3	16	4	0.25	12	0.75
26	May	8	8:20	9:02	42	-1	2	16	8	0.50	56	3.5
28	May	7	15:22	16:04	42	-1	1	16	4	0.25	89	5.56
29	May	7	15:23	15:42	19	1	3	16	13	0.81	165	10.31
30	May	7	14:11	14:29	18	1	3	16	11	0.69	181	11.31
31	May	7	9:39	10:24	45	-1	2	16	11	0.69	53	3.31
32	May	8	8:28	8:47	19	1	4	16	0	0	0	0
33	May	7	14:00	14:55	55	1	3	16	12	0.75	106	6.63
34	May	7	10:45	11:20	35	1	3	16	10	0.63	136	8.5
35	May	7	8:37	9:17	40	-1	1	16	2	0.13	92	5.75
Carpenter Bay												
10	May	6	13:15	13:45	30	6	6	16	2	0.13	0	0
11	May	6	10:30	10:45	15	0	5	16	0	0	70	4.38
12	May	6	14:00	14:25	25	1	3	16	1	0.06	45	2.81
13	May	6	14:58	15:22	24	1	4	16	2	0.13	358	22.38
14	May	6	8:31	9:05	34	0	3	16	18	1.13	221	13.81
15	May	6	9:30	10:00	30	0	2	16	17	1.06	166	10.38
17	May	6	13:14	13:31	17	3	4	16	1	0.06	61	3.81
18	May	6	10:30	10:49	19	2	4	16	2	0.13	138	8.63
19	May	6	13:40	14:00	20	0	3	16	5	0.31	173	10.81
20	May	6	8:11	8:34	23	0	2	16	6	0.38	27	1.69
21	May	6	8:44	9:02	18	2	3	16	1	0.06	38	2.38
Kunghit Island												
01	May	5	15:38	15:56	18	-1	3	16	1	0.06	39	2.44
02	May	5	10:06	10:50	44	0	1	16	10	0.63	97	6.06
03	May	5	9:15	9:44	29	0	2	16	8	0.50	62	3.88
04	May	5	8:29	8:47	18	0	3	16	2	0.13	118	7.38
07	May	5	8:38	8:56	18	0	1	16	0	0	3	0.19
71	May	5	13:39	13:58	19	1	2	16	0	0	28	1.75
79	May	5	9:21	9:37	16	1	4	16	1	0.06	45	2.81
OR01	May	5	14:52	15:22	30	-1	4	16	7	0.44	79	4.94
OR02	May	5	13:41	14:31	50	-1	3	16	15	0.94	39	2.44

Appendix 2. Habitat description of sites surveyed in southeast QCI, May 2007. The most common substrates are listed (1 = first, 2 = second, 3 = third) where substrate code 1 = smooth bedrock, 2 = bedrock with crevices, 3 = boulders, 4 = cobble, 5 = gravel, 6 = pea gravel, 7 = sand, 8 = shell, and 10 = crushed shell. Algae are grouped by growth characteristics for the most common species (Sp 1) and second most common (Sp 2) with percentage cover (%) for each grouping, where AA = *Alaria nana*, AC = articulated corallines, AF = *Agarum fimbriatum*, AG = *Agarum sp.*, AM = *Alaria marginata*, BH = brown filamentous, CO = *Costaria costata*, CY = *Cymathere triplicata*, DL = *Desmarestia ligulata*, DV = *Desmarestia viridis*, DY = *Dyctyota*, EG = *Egregia menziesii*, GB = green branched, GH = green filamentous, GI = *Gigartina* sp, IR = *Iridaea* sp (*Maziella* sp), LB = *Laminaria* , LT = *Laminaria setchellii*, MA = *Macrocystis integrifolia*, NT = *Nereocystis luetkeana*, PH = *Phyllospadix* sp, PL = *Pleurophycus gardneri*, PT = *Pterygophora californica*, RB = red branched, RF = red foliose, RH = red filamentous, SY = *Scytosiphon* sp, UL = *Ulva* sp., ZO = *Zostera sp.*

	Substrate			Canopy			Understorey			Turf			Encrusting
Site	1	2	3	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Cumshewa Inlet													
75	5	10		0			30	CY	GI	10	RB	SY	10
76	4			0			80	AG		20	AC		80
77	4	10	5	5	NT		30	CY	PL	0			10
78	3	10	4	5	MA		10	CY	CO	5	RF	BH	50
78-10	3	10	4	0			90	NT	CO	90	RB	RF	20
78-16	5	10	6	10	NT	MA	40	PL	CY	10	AC		10
78-18	3			30	NT	MA	90	DL	DV	50	AC	DY	50
79-54	3	10	5	10	MA		70	CY	RB	20	UL	RF	10
79-57	3	10	4	5	NT		20	PL	CY	5	IR		40
Selwyn Inlet													
65	2	4		15	NT		50	CO	CY	10	RH		90
66	1	3		5	EG	NT	5	LB	CY	5	AC		80
67	2	3	5	30	NT		40	DV	DL	70	RB	AC	70
68	2	4		60	NT		60	CO	DL	30	AC		90
69	1	2		70	NT		70	LB	AA	70	AC		10
70	2	3		20	NT		40	DL	DV	40	AC	RF	60
78-23	3	4		30	NT		40	CO	CY	50	DV	DL	70
79-58	2	3	5	30	NT		50	CO	CY	60	EN	RB	60
Tanu Island													
59	2			5	NT		20	DL	UL	40	AC		90
60	3	4		10	MA		60	CY	LB	20	AC		60
61	1	2		0			5	CO	AM	5	AC	BH	10
62	1	3	4	10	NT	MA	30	CY	CO	10	UL	RB	70
63	3	5	4	20	NT		40	CY	CO	60	AC	GF	40
64	2	7		10	MA		90	DL	CO	90	AC		90
73	4	5		20	MA		20	CY	LB	40	UL	RF	70
74	4	7		20	MA		30	EG	ZO	100	UL	AC	30

Appendix 2. Continued.

	Substrate			Canopy			Understorey			Turf			Encrusting
Site	1	2	3	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Upper Juan Perez													
44	2			40	NT		80	CO	DV	90	AC	UL	90
45	2	3	8	10	MA		10	CO	PL	30	UL	AC	90
46	1	2		5	NT	EG	5	AM	DL	5	AC	BH	10
48	1	2		50	NT		20	DV	CO	20	BH	UL	90
49	1	2	3	0			10	PH		10	BH	UL	70
50	3	4	7	10	MA		30	AF	LB	30	BH	UL	70
51	1	2	3	0			5	EG	IR	80	BH		60
52	2			30	NT		60	DL	CY	80	AC	RB	90
53	2			30	NT		60	LB	PT	50	ZO	AC	90
54	3	4		5	NT		5	CY		10	BH	AC	80
55	1	3	4	50	NT		70	DV	LT	20	AC	RB	80
56	1	2	3	30	NT		50	NT	CO	5	AC		70
57	2	3	4	0			0			20	AC		90
58	1	5	2	30	NT		60	CO	DL	40	AC	RB	60
Lower Juan Perez													
36	2			40	NT		50	CO	DL	40	AC		10
37	2			0			0			10	UL		90
38	1	2		20	NT	EG	80	CO	LT	30	AC	GH	90
39	1	2		30	NT	EG	80	CO	PT	90	AC	GB	10
40	1	2		5	EG	MA	5	DV		60	AC	GH	70
41	1	10	3	100	MA		30	MA	AF	20	AC	DY	80
42	2			5	NT		10	CO	DL	50	AC		90
43	2	3	4	60	NT		60	CO	DL	60	AC		90
78-60	2			5	NT		50	CO	DL	20	AC		90
78-61	2			90	NT		90	CO	DL	60	RH	AC	90
Skincuttle Inlet													
22	2	2	3	0			0			0			90
23	3	5	6	10	MA		60	CY	DE	10	AC		80
24	1	3	4	0			10	AF		20	AC	BH	80
25	2			0			20	DM	DV	30	UL	GH	70
26	1	10	2	5	MA		5	LB		20	AC	UL	60
28	2			10	EG	NT	30	CO	LB	70	IR	AC	80
29	2			10	NT		5	CO		10	AC		90
30	2			10	NT		10	CO	DL	30	AC		70
31	2	10		20	NT		20	CO	PL	30	AC		60
32	2	4		5	NT	MA	80	DL	LB	90	AC		90
33	3	4	5	40	NT		40	CY	AM	20	UL	GH	90
34	1	3	4	20	NT		20	AL	CO	5	AC	UL	90
35	3	10	4	30	NT		50	CO	CY	30	AC	UL	70
Carpenter Bay													
10	10	2	4	60	MA		20	AF	LS	30	AC		30
11	1	2		0			5	RB	DL	10	AC	BH	90
12	1	3	4	20	MA		20	LB	AF	30	AC	DY	90
13	1	10	4	0			0			10	BH	RH	90
14	1	3	7	0			2	NT		2	UL		10

Appendix 2. Continued.

	Substrate			Canopy			Understorey			Turf			Encrusting
Site	1	2	3	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Carpenter Bay													
15	2	10	3	10	NT		40	CO	NT	40	UL	BH	90
17	2	4	10	0			0			10	ZO		40
18	3	4	5	5	NT		0			10	AC		80
19	2	3		0			0			0			80
20	2			10	NT		10	DL		40	AC		80
21	3	4	2	5	NT		0			20	AC		80
Kunghit Island													
01	2	3	4	0			10	PH		40	AC		80
02	3	7		10	MA	NT	10	CY	CO	10	DV	AC	90
03	1	3		0			2	PT		2	AC		10
04	1	3		5	NT		5	DL		5	AC	UL	10
07	4	7	3	10	MA		40	CY	DL	20	AC		20
71	2	3	4	5	NT		30	CY	AL	10	UL	AC	30
79	2	3	4	20	NT		80	CY	CO	10	UL		10
OR01	1	2		0			5	PH		5	AC		10
OR02	1	3	4	30	NT		50	CY	LT	20	RB	UL	90

Appendix 3. Exposed abalone mean SL and density estimates for all sites surveyed in southeast QCI, May 2007. (-) denotes no data.

Site	Count of Exposed Abalone	Mean SL (mm)	Exposed Density by Size Group (mm SL) <70	≥70	≥100	Total
Cumshewa Inlet						
75	0	-	0.00	0.00	0.00	0.00
76	0	-	0.00	0.00	0.00	0.00
77	0	-	0.00	0.00	0.00	0.00
78	0	-	0.00	0.00	0.00	0.00
78-10	0	-	0.00	0.00	0.00	0.00
78-16	0	-	0.00	0.00	0.00	0.00
78-18	0	-	0.00	0.00	0.00	0.00
79-54	0	-	0.00	0.00	0.00	0.00
79-57	0	-	0.00	0.00	0.00	0.00
Selwyn Inlet						
65	2	80.5	0.00	0.13	0.00	0.13
66	6	53.2	0.31	0.06	0.00	0.38
67	6	45.2	0.38	0.00	0.00	0.38
68	2	47.0	0.13	0.00	0.00	0.13
69	4	37.3	0.25	0.00	0.00	0.25
70	7	60.3	0.38	0.06	0.00	0.44
78-23	2	80.0	0.00	0.13	0.00	0.13
79-58	8	65.8	0.31	0.19	0.00	0.50
Tanu Island						
59	13	71.8	0.19	0.63	0.06	0.81
60	21	89.7	0.13	1.19	0.44	1.31
61	2	77.0	0.06	0.06	0.00	0.13
62	7	80.4	0.00	0.44	0.00	0.44
63	23	75.3	0.38	1.06	0.00	1.44
64	0	-	0.00	0.00	0.00	0.00
73	7	71.9	0.19	0.25	0.00	0.44
74	0	-	0.00	0.00	0.00	0.00
Upper Juan Perez Sound						
44	4	54.8	0.25	0.00	0.00	0.25
45	4	89.0	0.00	0.25	0.06	0.25
46	27	48.4	1.63	0.06	0.00	1.69
48	7	36.9	0.44	0.00	0.00	0.44
49	8	72.1	0.19	0.31	0.00	0.50
50	2	76.5	0.06	0.06	0.06	0.13
51	0	-	0.00	0.00	0.00	0.00
52	8	48.5	0.44	0.06	0.00	0.50
53	9	51.3	0.56	0.00	0.00	0.56
54	35	70.5	1.06	1.13	0.25	2.19
55	14	77.4	0.19	0.69	0.06	0.88
56	2	49.5	0.13	0.00	0.00	0.13
57	1	56.0	0.06	0.00	0.00	0.06
58	1	65.0	0.06	0.00	0.00	0.06

Appendix 3. Continued

Site	Count of Exposed Abalone	Mean SL (mm)	Exposed Density by Size Group (mm SL) <70	≥70	≥100	Total
Lower Juan Perez Sound						
36	2	32.5	0.13	0.00	0.00	0.13
37	11	47.1	0.69	0.00	0.00	0.69
38	25	49.5	1.25	0.31	0.00	1.56
39	6	58.2	0.31	0.06	0.00	0.38
40	14	17.6	0.88	0.00	0.00	0.88
41	8	99.6	0.13	0.38	0.38	0.50
42	7	50.7	0.38	0.06	0.00	0.44
43	10	51.3	0.56	0.06	0.00	0.63
78-60	8	38.4	0.44	0.06	0.00	0.50
78-61	34	37.9	2.00	0.13	0.00	2.13
Skincuttle Inlet						
22	10	40.6	0.63	0.00	0.00	0.63
23	6	111.3	0.00	0.38	0.31	0.38
24	13	77.1	0.25	0.56	0.06	0.81
25	4	74.0	0.13	0.13	0.00	0.25
26	7	71.6	0.19	0.25	0.13	0.44
28	4	44.0	0.25	0.00	0.00	0.25
29	13	63.0	0.56	0.25	0.00	0.81
30	11	55.5	0.63	0.06	0.00	0.69
31	11	64.2	0.50	0.19	0.00	0.69
32	0	-	0.00	0.00	0.00	0.00
33	12	78.6	0.19	0.56	0.06	0.75
34	10	60.4	0.56	0.06	0.00	0.63
35	2	48.5	0.13	0.00	0.00	0.13
Carpenter Bay						
10	2	83.5	0.06	0.06	0.06	0.13
11	0	-	0.00	0.00	0.00	0.00
12	1	85.0	0.00	0.06	0.00	0.06
13	2	63.5	0.13	0.00	0.00	0.13
14	18	55.4	0.94	0.19	0.00	1.13
15	17	48.2	1.06	0.00	0.00	1.06
17	1	55.0	0.06	0.00	0.00	0.06
18	2	62.0	0.06	0.06	0.00	0.13
19	5	45.2	0.31	0.00	0.00	0.31
20	6	73.5	0.13	0.25	0.00	0.38
21	1	54.0	0.06	0.00	0.00	0.06
Kunghit Island						
01	1	54.0	0.06	0.00	0.00	0.06
02	10	85.1	0.06	0.56	0.13	0.63
03	8	51.3	0.44	0.06	0.00	0.50
04	2	63.0	0.06	0.06	0.00	0.13
07	0	-	0.00	0.00	0.00	0.00
71	0	-	0.00	0.00	0.00	0.00
79	1	102.0	0.00	0.06	0.06	0.06
OR01	7	53.7	0.31	0.13	0.00	0.44
OR02	15	77.4	0.25	0.69	0.06	0.94

Appendix 4. 'All sizes' exposed abalone density and number of quadrats by site for all survey years in southeast QCI.

Blanks indicate no samples taken. * Represents perpendicular transect survey design; i.e. not 'Breen' design.

	'All sizes' abalone density (number/m^2)									Total number of quadrats per site								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Cumshewa Inlet																		
75	1.13			0.44	0.06	0.00	0.00	0.00	0.00	16			16	16	32	16	8	16
76	2.69	2.19		0.13	0.38	0.19		0.00	0.00	16	16		16	16	32		16	16
77	1.44			0.00		0.06	0.00	0.00	0.00	16			4		32	16	8	16
78	0.88			1.50	0.75	0.06	0.00	0.00	0.00	16			16	16	32	16	8	16
78-10	2.88								0.00									16
78-16	1.00								0.00									16
78-18	1.38								0.00									16
79-54		1.02*							0.00									16
79-57		1.42*							0.00									16
Selwyn Inlet																		
65	1.06		0.13	0.50	0.06	0.25	0.31	0.00	0.13	16		16	16	16	32	16	8	16
66	0.63	1.38	0.13	0.31	0.06	0.34	0.88	0.00	0.38	16	16	16	16	16	32	16	8	16
67	0.94		0.00	0.56	0.31	0.09	0.25	0.06	0.38	16		8	16	16	32	16	16	16
68	1.13		0.19	1.19	0.63	0.13	0.50	0.13	0.13	16		16	16	16	32	16	16	16
69	3.88	3.06	0.06	0.19	0.13	0.19	0.00	0.06	0.25	16	16	16	16	16	32	16	16	16
70	3.63	2.13	0.31	0.25	0.06	0.06	0.25	0.00	0.44	16	16	16	16	16	32	16	8	16
78-23	3.25								0.13									16
79-58		4.06							0.50									16
Tanu Island																		
59	1.44		0.88	1.06	0.63	0.81	0.94	0.63	0.81	16		16	16	16	64	16	16	16
60			1.25	0.63	0.00	0.19	1.38	0.81	1.31			16	16	8	64	16	16	16
61	1.53		0.31	0.00	0.00	0.28	0.13	0.25	0.13	32		16	16	8	32	16	16	16
62			0.56	0.81	0.63	0.16	0.19	0.00	0.44			16	16	16	32	16	8	16
63	1.44		0.19	0.19	0.56	0.31	1.13	0.38	1.44	16		16	16	16	32	16	16	16
64	2.19		0.06	0.75	0.06	0.03	0.38	0.31	0.00	16		16	16	16	32	16	16	16
73				1.00	0.13	0.38	0.06	0.00	0.44				16	16	32	16	8	16
74				0.13	0.06	0.59	0.06	0.31	0.00				16	16	32	16	16	16

Appendix 4. Continued.

	'All sizes' abalone density (number/m^2)									Total number of quadrats per site								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Lower Juan Perez																		
36	2.44		0.00	0.00	0.00	0.22	0.31	0.00	0.13	16		8	16	16	32	16	8	16
37	1.13		0.00	0.38	0.19	0.06	0.25	0.88	0.69	16		8	16	16	32	16	16	16
38	2.44		1.00	0.69	0.94	0.41	1.00	0.25	1.56	16		16	16	16	32	16	16	16
39	6.38		1.81	0.88	0.31	0.28	0.38	0.38	0.38	13		16	16	16	32	16	16	16
40	1.00		0.13	0.06	0.08	0.03	0.00	0.00	0.88	16		16	16	48	32	16	8	16
41	0.25		0.06	0.06	0.00	0.06	0.13	0.19	0.50	16		16	16	16	32	16	16	16
42	16.56		0.06	1.56	0.63	0.52	0.38	0.38	0.44	16		16	16	16	64	16	16	16
43	9.38		0.31	0.81	0.69	0.27	0.44	0.00	0.63	16		16	16	16	64	16	8	16
78-60	3.44								0.50									16
78-61	7.38								2.13									16
Upper Juan Perez																		
44	6.56		0.13	0.44	0.06	0.06	0.19	0.13	0.25	16		16	16	16	32	16	16	16
45	4.25		0.75	0.63	0.81	0.13	0.06	0.00	0.25	16		16	16	16	32	16	8	16
46	7.06		0.50	4.00	1.44	0.22	0.38	1.50	1.69	16		16	16	16	32	16	16	16
47			0.00									8						
48	3.63		1.19	0.81	0.44	0.19	0.00	0.25	0.44	16		16	16	16	48	16	16	16
49	1.81		0.56	0.88	2.10	0.25	0.13	0.25	0.50	16		16	16	48	64	16	16	16
50	0.63		1.19	0.38	0.56	0.22	0.06	0.25	0.13	16		16	16	16	32	16	16	16
51	0.75		0.00	0.50	0.38	0.23	0.50	0.44	0.00	16		16	16	16	64	16	16	16
52	8.86		2.00	0.50	0.69	0.06	0.38		0.50	7		16	16	16	32	16		16
53	8.13		0.31	0.75	0.94	0.00	0.81	0.00	0.56	16		16	16	16	32	16	8	16
54	0.63		1.00	1.50	0.50	0.27			2.19	16		16	16	16	64			16
55	5.88		0.88	2.56	1.19	0.38	1.00	0.31	0.88	16		16	16	16	32	16	16	16
56	7.25		1.75	1.13	1.75	0.59	0.25	0.38	0.13	16		16	16	16	32	16	16	16
57	2.63		1.00	0.25	0.00	0.00	0.06	0.06	0.06	16		16	16	16	32	16	16	16
58	3.38		0.06	0.25	0.25	0.00	0.38	0.56	0.06	16		16	16	16	32	16	16	16
Skincuttle Inlet																		
22	1.63		0.06	0.00	0.63	0.09	1.06	0.06	0.63	16		16	0	16	32	16	16	16
23	1.13		0.69	0.63	0.31	0.03	0.13	0.19	0.38	16		16	16	16	32	16	16	16
24	0.75		0.81	1.13	0.38	0.25	0.13	0.00	0.81	16		16	16	16	48	16	8	16

Appendix 4. Continued.

	'All sizes' abalone density (number/m^2)									Total number of quadrats per site								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Skincuttle Inlet																		
25	2.25		0.75						0.25	16		16						16
26	0.56		2.00	2.13	1.25	0.34	0.56	0.31	0.44	16		16	16	16	32	16	16	16
27	0.63		0.00	0.06	0.06	0.06		0.00		16		8	16	16	32		8	
28	3.06		1.13	1.13	0.31	0.88	0.25	0.00	0.25	16		16	16	16	32	16	8	16
29	0.94		0.69	0.38	0.19	0.34	0.38	0.25	0.81	16		16	16	16	32	16	16	16
30	3.31		1.25	0.44	0.88	0.53	0.69	0.25	0.69	16		16	16	16	32	16	16	16
31	1.75		0.50	0.94	0.25	0.31	0.13	0.31	0.69	16		16	16	16	32	16	16	16
32	5.75		0.00	0.50	0.13	0.09	0.00	0.13	0.00	16		8	16	16	32	16	16	16
33	3.00		0.81	0.75	0.06	1.16	1.00	0.63	0.75	16		16	16	16	32	16	16	16
34	6.13		0.94	0.44	0.19	0.25	0.94	0.00	0.63	16		16	16	16	28	16	8	16
35	0.31		0.38	0.50	0.06	0.34	0.25	0.00	0.13	16		16	16	16	32	16	8	16
72				1.00									16					
Carpenter Bay																		
10	1.06		0.69	0.56	0.31	0.34	0.50	0.00	0.13	16		16	16	16	32	16	8	16
11	0.19		0.00	0.19	0.06	0.16	1.06	1.06	0.00	16		8	16	16	32	16	16	16
12	0.13		0.19	0.19	0.31	0.22	0.88	0.63	0.06	16		16	16	16	32	16	16	16
13	2.47		0.42						0.13	15		12						16
14	2.31		0.56	0.63	1.56	0.31	0.38	0.38	1.13	16		16	16	16	32	16	16	16
15	3.38		0.50	0.44	0.38	0.97	3.00	1.13	1.06	16		16	16	16	32	16	16	16
16	2.56		0.06							16		16						
17	1.19		0.06	0.56	0.13	0.41	0.63	0.00	0.06	16		16	16	16	32	16	8	16
18	1.44		0.81	0.25	0.25	0.63	0.31	0.50	0.13	16		16	16	16	32	16	16	16
19	1.00		0.00	0.38	0.31	0.91	0.50	0.00	0.00	16		16	16	16	32	16	16	16
20	1.13		1.63	0.07	0.31	0.72	2.50	2.44	0.38	16		16	15	16	32	16	16	16
21	0.94		0.00	0.00	0.00	0.03	0.44	0.00	0.06	16		8	8	8	32	16	8	16

Appendix 4. Continued.

	'All sizes' abalone density (number/m^2)									Total number of quadrats per site								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Kunghit Island																		
01		1.56	1.06	1.06	1.94	0.47	0.31	2.00	0.06	16	16	16	16	16	32	16	16	16
02		2.38	0.44	1.06	1.50	0.22	0.94	0.75	0.63	16	16	16	16	16	32	16	16	16
03		0.75	0.38	0.38	0.94	1.63	0.88	1.19	0.50	16	8	16	16	16	32	16	16	16
04			0.13	0.44	0.13	0.00		0.56	0.13			16	16	16	32		16	16
05			0.00									8						
06			0.50	0.00								16	8					
07			0.19	0.13	0.19	0.16	0.13	0.50	0.00			16	16	16	32	16	16	16
08			0.06									16						
09			0.44									16						
71				0.31	0.19	0.19	0.69	0.38	0.00				16	16	32	16	16	16
79					0.31	0.03	0.31	0.13	0.06					16	32	16	16	16
OR01							1.25		0.44									16
OR02							2.19		0.94									16

Appendix 5. Mature (≥ 70 mm SL) and large (≥ 100 mm SL) exposed abalone densities by site for all survey years in southeast QCI. Blanks indicate no samples taken.

	Mature abalone density (number/m^2)									Large abalone density (number/m^2)								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Cumshewa Inlet																		
75	1.05			0.44	0.06	0.00	0.00	0.00	0.00	0.84			0.44	0.06	0.00	0.00	0.00	0.00
76	0.96			0.13	0.25			0.00	0.00	0.08			0.06	0.13			0.00	0.00
77	0.81			0.00		0.06	0.00	0.00	0.00	0.44			0.00		0.06	0.00	0.00	0.00
78	0.88			1.50	0.69	0.06	0.00	0.00	0.00	0.75			1.50	0.69	0.03	0.00	0.00	0.00
78-10	2.16								0.00	1.44								0.00
78-16	0.76								0.00	0.18								0.00
78-18	0.89								0.00	0.21								0.00
79-54									0.00									0.00
79-57									0.00									0.00
Selwyn Inlet																		
65			0.06	0.44	0.06	0.09	0.06	0.00	0.13	0.05		0.00	0.13	0.00	0.06	0.00	0.00	0.00
66		0.75	0.13	0.25	0.06	0.17	0.25	0.00	0.06	0.31	0.38	0.06	0.13	0.00	0.03	0.00	0.00	0.00
67			0.00	0.44	0.06	0.00	0.13	0.00	0.00	0.14		0.00	0.19	0.06	0.00	0.00	0.00	0.00
68	0.99		0.00	0.63	0.38	0.03	0.00	0.00	0.00	0.40		0.00	0.25	0.25	0.00	0.00	0.00	0.00
69		2.06	0.00	0.13	0.06	0.19	0.00	0.06	0.00	0.39	0.20	0.00	0.06	0.00	0.06	0.00	0.00	0.00
70		1.74	0.16	0.00	0.06	0.03	0.06	0.00	0.06	0.54	0.39	0.05	0.00	0.06	0.03	0.00	0.00	0.00
78-23									0.13	1.63								0.00
79-58		3.50							0.19		1.90							0.00
Tanu Island																		
59			0.75	1.00	0.50	0.63	0.88	0.13	0.63	0.36		0.13	0.69	0.25	0.29	0.38	0.00	0.06
60			1.25	0.63	0.00	0.16	1.25	0.38	1.19			0.36	0.49	0.00	0.14	0.69	0.00	0.44
61	1.43		0.25	0.00	0.00	0.06	0.06	0.00	0.06	0.40		0.19	0.00	0.00	0.00	0.00	0.00	0.00
62			0.56	0.44	0.38	0.09	0.13	0.00	0.44			0.25	0.25	0.13	0.03	0.06	0.00	0.00
63	0.68		0.00	0.09	0.44	0.24	0.73	0.25	1.06	0.21		0.00	0.00	0.00	0.00	0.07	0.00	0.00
64	2.12		0.06	0.71	0.06	0.03	0.38	0.06	0.00	1.42		0.00	0.44	0.06	0.00	0.25	0.00	0.00
73				1.00	0.13	0.34	0.06	0.00	0.25				0.94	0.13	0.25	0.00	0.00	0.00
74				0.13	0.06	0.22	0.06	0.31	0.00				0.13	0.06	0.16	0.06	0.13	0.00

Appendix 5. Continued.

	Mature abalone density (number/m^2)									Large abalone density (number/m^2)								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Lower Juan Perez																		
36	0.13		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
37			0.00	0.21	0.00	0.03	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
38			0.44	0.44	0.75	0.20	0.47	0.13	0.31	0.24		0.00	0.06	0.25	0.10	0.13	0.00	0.00
39	0.38		0.13	0.00	0.19	0.07	0.19	0.06	0.06	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
40			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
41			0.06	0.06	0.00	0.06	0.06	0.06	0.38	0.00		0.06	0.00	0.00	0.06	0.00	0.06	0.38
42	11.52		0.00	0.69	0.19	0.03	0.06	0.00	0.06	1.25		0.00	0.13	0.06	0.02	0.00	0.00	0.00
43			0.19	0.06	0.13	0.02	0.00	0.00	0.06	0.47		0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-60									0.06	0.34								0.00
78-61	2.00								0.13	0.20								0.00
Upper Juan Perez																		
44	3.13		0.06	0.31	0.00	0.03	0.13	0.00	0.00	0.06		0.00	0.13	0.00	0.00	0.00	0.00	0.00
45	1.55		0.31	0.31	0.50	0.06	0.06	0.00	0.25	0.13		0.19	0.06	0.25	0.00	0.00	0.00	0.06
46	1.67		0.06	0.31	0.00	0.03	0.00	0.25	0.06	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
47			0.00									0.00						
48	1.63		0.94	0.38	0.25	0.15	0.00	0.00	0.00	0.54		0.38	0.13	0.06	0.13	0.00	0.00	0.00
49			0.49	0.82	1.71	0.23	0.00	0.19	0.31	1.63		0.42	0.70	0.33	0.14	0.00	0.00	0.00
50			1.13	0.38	0.56	0.22	0.00	0.25	0.06	0.56		0.75	0.31	0.44	0.09	0.00	0.19	0.06
51			0.00	0.50	0.38	0.23	0.50	0.44	0.00	0.68		0.00	0.44	0.31	0.23	0.38	0.31	0.00
52	0.00		0.00	0.00	0.00	0.06	0.00		0.06	0.00		0.00	0.00	0.00	0.00	0.00		0.00
53			0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22		0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	0.25		0.77	1.16	0.44	0.20			1.13	0.00		0.08	0.41	0.19	0.08			0.25
55			0.56	2.18	0.88	0.34	0.81	0.19	0.69	3.53		0.06	0.26	0.56	0.09	0.25	0.13	0.06
56			1.19	1.00	1.25	0.47	0.25	0.19	0.00	0.36		0.13	0.50	0.44	0.09	0.06	0.19	0.00
57			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13		0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	1.66		0.00	0.08	0.00	0.00	0.25	0.25	0.00	0.12		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Skincuttle Inlet																		
22			0.00	0.00	0.00	0.03	0.06	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
23			0.69	0.63	0.31	0.03	0.13	0.19	0.38	0.11		0.28	0.21	0.13	0.03	0.06	0.19	0.31
24	0.75		0.68	1.00	0.38	0.25	0.06	0.00	0.56	0.40		0.07	0.19	0.00	0.04	0.00	0.00	0.06

Appendix 5. Continued.

	Mature abalone density (number/m^2)									Large abalone density (number/m^2)								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Skincuttle Inlet																		
25			0.52						0.13	0.11		0.29						0.00
26	0.56		1.81	2.06	1.00	0.25	0.50	0.19	0.25	0.51		0.45	0.86	0.25	0.00	0.25	0.00	0.13
27	0.42		0.00	0.06	0.06	0.06		0.00		0.16		0.00	0.06	0.06	0.03		0.00	
28	0.27		0.00	0.06	0.00	0.06	0.00	0.00	0.00	0.07		0.00	0.00	0.00	0.00	0.00	0.00	0.00
29			0.00	0.06	0.06	0.03	0.06	0.06	0.25	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
30			0.00	0.00	0.00	0.13	0.00	0.06	0.06	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
31			0.50	0.88	0.19	0.22	0.06	0.19	0.19	0.09		0.28	0.69	0.06	0.19	0.00	0.06	0.00
32	4.28		0.00	0.13	0.06	0.00	0.00	0.00	0.00	0.45		0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	2.51		0.75	0.63	0.06	1.03	0.94	0.44	0.56	1.10		0.31	0.38	0.00	0.59	0.50	0.25	0.06
34	1.74		0.81	0.31	0.06	0.16	0.69	0.00	0.06	0.26		0.19	0.06	0.00	0.00	0.00	0.00	0.00
35			0.38	0.50	0.00	0.31	0.25	0.00	0.00	0.03		0.31	0.13	0.00	0.19	0.19	0.00	0.00
72				1.00									0.88					
Carpenter Bay																		
10	0.69		0.52	0.51	0.31	0.34	0.44	0.00	0.06	0.06		0.06	0.28	0.19	0.31	0.44	0.00	0.06
11	0.19		0.00	0.13	0.06	0.16	0.50	0.69	0.00	0.06		0.00	0.00	0.00	0.03	0.00	0.00	0.00
12			0.19	0.19	0.31	0.13	0.88	0.56	0.06	0.10		0.06	0.09	0.06	0.00	0.81	0.38	0.00
13	0.33		0.00						0.00	0.00		0.00						0.00
14			0.44	0.19	0.81	0.28	0.00	0.06	0.19	0.93		0.06	0.00	0.00	0.00	0.00	0.00	0.00
15	2.04		0.19	0.06	0.06	0.53	1.44	0.56	0.00	0.13		0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	1.31		0.00							0.20		0.00						
17			0.06	0.21	0.00	0.28	0.44	0.00	0.00	0.06		0.00	0.00	0.00	0.00	0.13	0.00	0.00
18	1.19		0.81	0.21	0.19	0.36	0.31	0.50	0.06	0.44		0.38	0.04	0.06	0.20	0.25	0.19	0.00
19			0.00	0.06	0.06	0.22	0.06	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.50		0.75	0.07	0.25	0.44	1.13	0.28	0.25	0.00		0.00	0.00	0.00	0.06	0.13	0.00	0.00
21			0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.19		0.00	0.00	0.00	0.03	0.00	0.00	0.00

Appendix 5. Continued.

	Mature abalone density (number/m^2)									Large abalone density (number/m^2)								
Site	1978	1979	1984	1987	1990	1994	1998	2002	2007	1978	1979	1984	1987	1990	1994	1998	2002	2007
Kunghit Island																		
01		1.02	1.00	0.75	1.63	0.34	0.06	1.63	0.00		0.30	0.12	0.19	0.38	0.13	0.00	0.31	0.00
02		2.12	0.44	0.84	0.69	0.00	0.67	0.38	0.56		0.96	0.13	0.11	0.31	0.00	0.00	0.00	0.13
03		0.64	0.38	0.27	0.81	1.27	0.56	0.69	0.06		0.43	0.21	0.05	0.13	0.16	0.13	0.25	0.00
04			0.00	0.29	0.00	0.00		0.19	0.06			0.00	0.15	0.00	0.00		0.06	0.00
05			0.00									0.00						
06			0.21	0.00								0.07	0.00					
07			0.13	0.00	0.19	0.16	0.13	0.19	0.00			0.06	0.00	0.06	0.06	0.13	0.06	0.00
08			0.06									0.00						
09			0.31									0.06						
71				0.31	0.19	0.19	0.69	0.31	0.00				0.31	0.13	0.13	0.50	0.06	0.00
79					0.25	0.03	0.25	0.13	0.06					0.13	0.00	0.00	0.06	0.06
OR01									0.13									0.00
OR02									0.69									0.06